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The research activities focused on three areas. The first area is the study of liquid crystal polymers in certain confined and free geometries. The second is a study of the interfacial instability for layered viscoelastic fluids governed by Johnson-Segalman constitutive equations. The third is the development of ENO schemes for a compressible Maxwell model which exhibits pure hyperbolicity at all flow configurations.

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~~Annual~~ Report

June 1, 1992-May 31, 1995

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The research activities in the past year (June, 1994-May, 1995) were focused on three areas. The first area is the study of liquid crystal polymers in certain confined and free geometries. The second is a study of the interfacial instability for layered viscoelastic fluids governed by Johnson-Segalman constitutive equations. The third is the development of ENO schemes for a compressible Maxwell model which exhibits pure hyperbolicity at all flow configurations.

Free surface jet flows of liquid crystal polymers and its applications to the industrial fiber spinning processes

The focus of this study is the modeling of free surface flows of liquid crystal polymers encountered in industrial applications through asymptotic analyses and computations. We adopt a kinetic theory of Doi type, developed by Bhave et al., as the constitutive equation. By exploring the structure of the stress tensor which in turn depends on the orientation tensor, we proposed a biaxial representation of the orientation tensor with uniaxial symmetry at the flow centerline. Combining this ansatz with a double expansion asymptotic expansion for the velocity and pressure as well as a single expansion for the radius of the free surface with respect to the slenderness ratio (the ratio of the radial length scale to the axial length scale), we derived a spectrum of model equations that represents different competing physical effects at leading order. Some of these models have been applied to model the fiber spinning processes involving polymeric crystalline materials.

Through studying the model equations, we find that the orientation effect may contribute stabilizing and destabilizing effect to the jet flow depending on the internal molecular phase, besides the hydrodynamic instability that might have existed in their Newtonian counterparts. If the orientational instability exists, the dimensionality of the unstable manifold depends on the polymer concentration. The details of the analysis is documented in a upcoming paper by Qi Wang, M. G. Forest, and S. E. Bechtel. A sequel on the application to the fiber spinning problem will soon follow.

Some preliminary studies on linear stability of polymeric liquid crystal flows in pipes and layers are currently under way.

Interfacial instability in coextrusion of two viscoelastic fluids

This is the first phase of our study on interfacial instability between two viscoelastic fluids. In this phase, we are interested in the linear stability of the fluid interface for certain types of viscoelastic fluids. We start with the Johnson-Segalman constitutive equation, which includes the Oldroyd B and Maxwell equation as special cases. The corresponding stability problem of Newtonian fluids have been studied extensively at the long and short wave range. Recently, a report on the study of nonaxisymmetric perturbations and related stability for Newtonian fluids has become available. Our study aims at generalizing the study to viscoelastic fluids. Due to the possible elastic stratification, this is a nontrivial generalization! Some preliminary results have been obtained for long and short wave limit. A comprehensive study for the intermediate wave length and the nonaxisymmetric perturbations is currently underway. This result will be reported in a forthcoming proceedings article at the ASME annual meeting late this year.

Numerical simulation of purely hyperbolic Maxwell fluids in complex geometries

This is an ongoing project. It is well-known that all the existing numerical codes fail at high Debra number in viscoelastic flow simulations. Many believe that the culprit for failure is that the solver loses accuracy at certain high Debra number, which causes fictitious stress values and in turn causes the system change-of-type. To understand this phenomenon, an explicit solver for a purely hyperbolic constitutive model would be desirable. We are using ENO methodology to design a solver to compute 3-D axisymmetric flows governed by a purely hyperbolic Maxwell constitutive equation. Owing to its success in computations of gas dynamics, ENO methodology fits very well into this problem even though the governing system is not a conservative system. Our solver simulates the viscoelastic flow in a geometry where a confined domain is connected to a free surface field. Our ultimate goal in the project is to analyze the high Debra number mechanism and study the nonlinear stability issues such as the influence of upstream disturbances to the downstream free surface.